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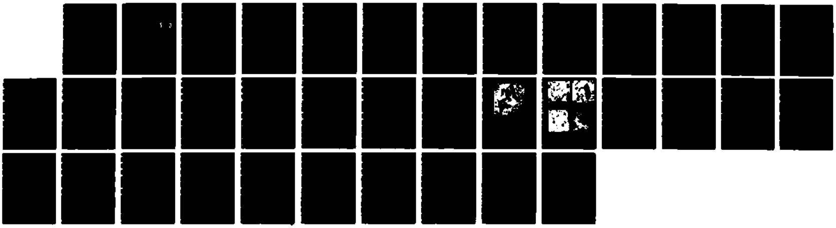

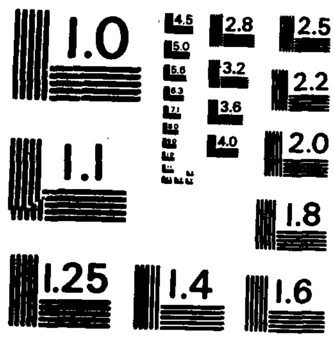

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STUDIES ON THE INHALATION TOXICITY OF DYES PRESENT IN COLORED SMOKE MUNITIONS: AEROSOL MEASUREMENTS IN THE WORKPLACE AT PINE BLUFF, ARKANSAS

Final Report

Rogene F. Henderson, Principal Investigator
George J. Newton
Yung-Sung Cheng
Bean Chen
Ray L. Hanson

September 5, 1985

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, MD 21701-5012

Army Project Order 83PP3807

Inhalation Toxicology Research Institute
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The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents

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Industrial hygiene

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Lovelace Inhalation Toxicology Research Institute has been conducting inhalation toxicity studies on the organic dyes used in colored smoke munitions to provide a health hazard assessment for the workers engaged in fabrication of these smoke munitions. This report summarizes the results of a field sampling effort at the United States Army's Pine Bluff Arsenal to measure the size distributions and aerosol concentrations to which workers might be exposed.

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Aerosol samples were taken in the workplace during routine operation of the colored smoke grenade fabrication facility. During this sampling period, the M18 yellow smoke grenade was being produced. Filter samples were used to determine the concentration of airborne dye-containing material and cascade impactors were used to determine the particle size distributions. Aerosol samples were analyzed for solvent yellow (SY) by reverse-phase, high-pressure liquid chromatography (HPLC). Dye-containing aerosol concentrations ranged from 0.1 to about 1.5 mg/m^3 in the general vicinity of some of the workers. Chemical analyses showed that 40 percent of the total airborne particulate matter was SY dye. Impactor samples indicated that 50-70% of the aerosol was of a size that could be inhaled. Thus the range of air concentrations for worker exposures to the SY dye was <0.5 mg/m^3. Inside protective acrylic curtains that are used to reduce personnel exposures, the concentration was about 10 fold higher with a maximum of 32 mg/m^3 at a fill and press station.

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EXECUTIVE SUMMARY

The Lovelace-Inhalation Toxicology Research Institute has been conducting inhalation toxicity studies on the organic dyes used in colored smoke munitions to provide an improved human health risk estimate for the workers engaged in fabrication of these smoke munitions. This report summarizes the results of a field sampling effort at the United States Army's Pine Bluff Arsenal to measure the size distributions and aerosol concentrations to which workers might be exposed.

Aerosol samples were taken in the workplace during routine operation of the colored smoke grenade fabrication facility. During this sampling period, the M18 yellow smoke grenade was being produced. Filter samples were used to determine the concentration of airborne dye-containing material and cascade impactors were used to determine the particle size distributions. Aerosol samples were analyzed for solvent yellow (SY) by reverse-phase, high-pressure liquid chromatography (HPLC). Dye-containing aerosol concentrations ranged from 0.1 to about 1.5 mg/m^3 in the general vicinity of some of the workers. Chemical analyses showed that 40 percent of the total airborne particulate matter was SY dye. Impactor samples indicated that 50-70% of the aerosol was of a size that could be inhaled. Thus the air concentrations for worker exposures to the SY dye was < 0.5 mg/m^3. Inside protective acrylic curtains that are used to reduce personnel exposures, the concentration was about 10 fold higher with a maximum of 32 mg/m^3 at a fill and press station.

FOREWORD

The authors acknowledge the contributions of all members of the staff of the Inhalation Toxicology Research Institute who helped in the completion of this work. The research was supported by the U. S. Army Medical Research and Development Command under a Memorandum of Understanding Agreement No. AT(29-2)-2138/3807 with the Lovelace Inhalation Toxicology Research Institute, which is operated for the U. S. Department of Energy under DOE Contract No. DE-AC04-76EV01013.

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INTRODUCTION

The objective of this study was to obtain air samples from different areas in a plant manufacturing a yellow colored smoke grenade and to quantitate the amount of dye material and particle size distribution in the air samples. These measurements were used to estimate the amount of dye to which workers may be exposed during manufacture of the colored munition.

The M18 colored smoke grenade is used by the United States military for signaling and marking. The M18 grenades release four colors: yellow, green, red and violet. The United States Army's Pine Bluff Arsenal located in Pine Bluff, Arkansas produces the M18 colored smoke grenade. Figure 1 illustrates the M18 colored smoke grenade manufacturing process. Raw materials are sifted or pulverized as required. The materials are weighed and manually loaded into a 166 liter mixer. Acetone is added to the dry powder as required to achieve the proper slurry consistency. Mixing is monitored by closed circuit television. As the acetone evaporates, granulation occurs in a wide variety of sizes. The mixture is transported to another building for drying in conventional tray dryers for about 8 hours. The smoke grenade mixture consists of the following components: potassium chlorate (26.5 percent), sodium bicarbonate (24.0 percent), sulfur (9.0 percent), organic dye (40.0 percent), and lubricant (stearic acid) (0.5 percent), (Miller 1983). The material passing acceptance tests is then ready for fill and press operations which occur in another building.

In the finished smoke grenade, the mixture is contained in a thick walled tinplated steel can approximately 6.0 cm (2.4-in.) in diameter and 11.4 cm (4.5-in.) in height. Grenade fabrication begins when a can, with a center

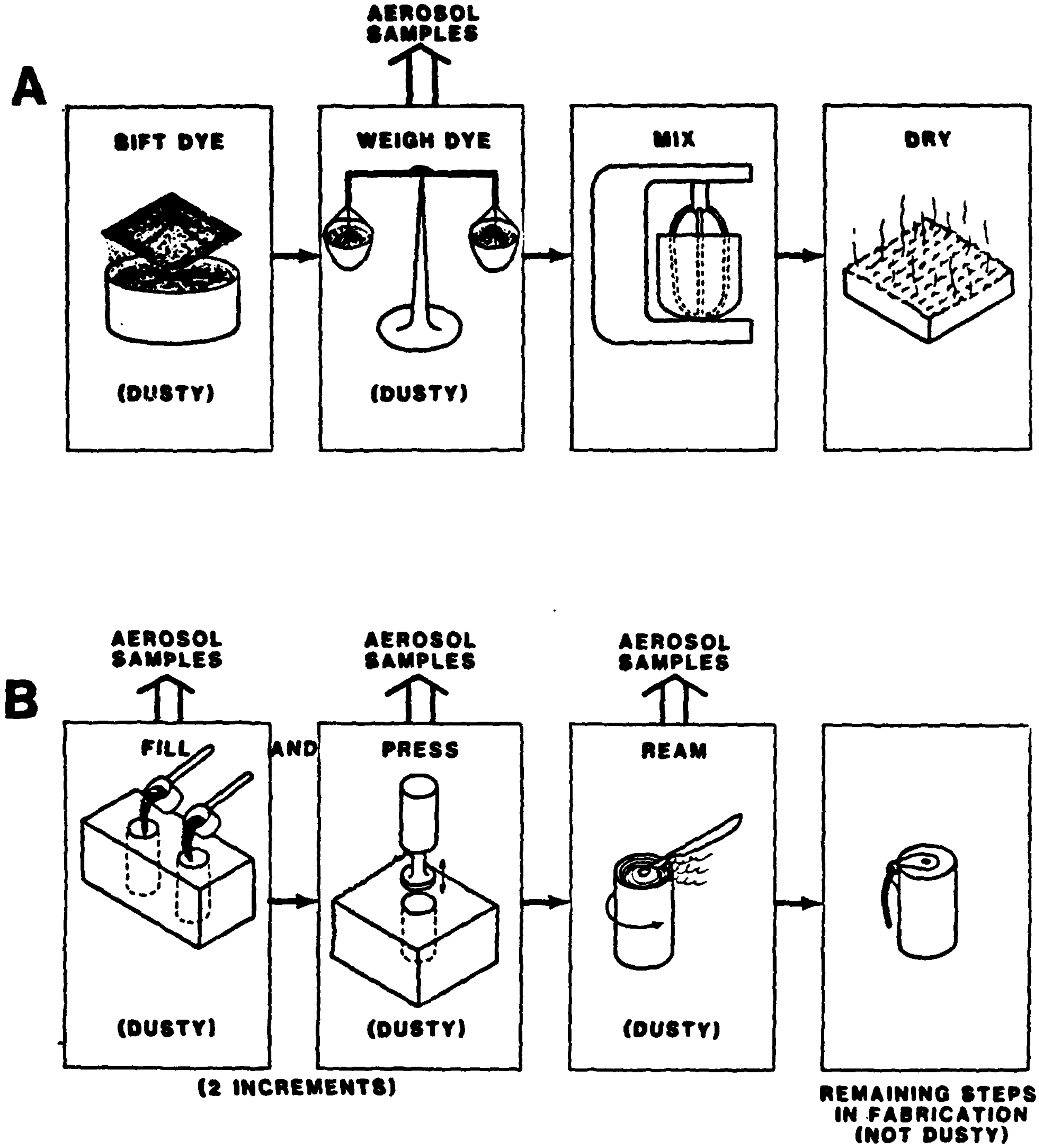

Figure 1. Schematic diagram showing some of the steps in the fabrication of the M18 colored smoke grenade. Figure 1-A shows some of the mix preparation operations conducted in Building No. 31-520 and includes: (1) sifting if required, (2) weighing of the bulk dye, (3) mixing and slurry preparations of the bulk mixture, and (4) drying of the bulk mixture which occurs in another building. Figure 1-B shows some of the operations in the actual grenade fabrication that are conducted in Building No. 33-350 and include: (1) fill, (2) press, (3) ream, and the remaining steps. Not shown are the 2 increments of fill and press. Note the arrows that indicate where aerosol samples were obtained.

hole forming mandrel in place, is placed in a clamshell mold brace and the mixture is manually ladled into the can. A hydraulic press consolidates the mix. This fill and press operation is repeated as required for each grenade type. During the field sampling study reported herein, the yellow M18 colored smoke grenade required two increments of consolidation. After the final fill and press operation, the clamshell mold brace is manually opened, the grenade is removed, and the center hole forming mandrel is removed. The proper fill height is achieved by cutting away excess compacted mixture with an automatic reaming machine. The M18 starter mix is applied as an acetone slurry of the following components (dry wt percent): potassium nitrate (43 percent), sulfur (17 percent), sodium bicarbonate (30 percent), and corn starch (10 percent) (Miller 1983). The starter mix is applied to the top of the consolidated smoke mix and also in the center hole. After application, the conveyor line carries the grenades through a drying oven where the acetone is driven off during a 15 minute cycle. A protective paper that had been placed around the grenade can is removed and acetone soaked wipes are used to clean any smoke mixture adhering to the outside of the can. The remaining steps in M18 grenade fabrication include: (1) lid sealing where a lid is attached to the grenade body with a double crimp seal using an electrically powered, manually controlled can sealing machine, (2) painting, (3) marking, (4) fuze insertion, and (5) final packaging. None of these last five steps produces significant quantities of dye containing aerosols.

Each grenade contains approximately 320 grams of the colored smoke mixture. In use, the grenade is ignited by the M201A1 fuze which ignites a thin layer of a starter mixture that covers the walls of the center core hole and the top of the compacted smoke mixture. Colored smoke is emitted through the center core hole out of the bottom of the grenade.

AEROSOL MEASUREMENTS AT THE PINE BLUFF ARSENAL

The aerosol characterization study was conducted in September, 1984, during routine fabrication of the yellow M18 smoke grenade. The yellow colored dye is 2-(2'-quinolinyl)-1,3-indandione, also sometimes referred to as QI (quinolyl indandione). In this report we will refer to the bulk dye, which may contain small amounts of impurities, as Solvent Yellow or SY. We will refer to the major component as QI. Other synonyms for SY are: (1) Chinoline Yellow, (2) Colour Index (C. I.) Solvent Yellow 33, (3) C. I. No. 47000.

The primary objective of this field sampling effort was to develop basic information on the dye-containing aerosols to which occupational workers could be exposed. Aerosol samples needed included breathing zone samples to determine: (1) the mass concentration in respirable sizes and (2) the size distribution parameters of mass median aerodynamic diameter (MMAD) and geometric standard deviation (σ_g). Additionally, the airborne mass concentration and size distribution parameters of dye-containing aerosols inside the acrylic curtains that are used to reduce dust along the production line were needed to assess the effectiveness of the curtains.

EXPERIMENTAL APPROACH

Based upon a site visit by ITRI scientists in May, 1984, three areas were selected for aerosol characterization studies: (1) the blend and mixing area, (2) the drying area, and (3) the actual fabrication area for the M18

colored smoke grenade. However, because of operational limitations, we were unable to obtain any aerosol samples in the drying area. The actual aerosol sampling sites are listed in Table 1. These sampling sites were: (1) the weighing station for the pure organic dye in cubicle #15, Building #31-520, and also in the hallway of Building #31-520, and (2) several stations along the main production line which is located in Building #33-350. These sampling sites in the M-18 grenade production area were: (1) the partial fill and press operation, (2) the complete or final fill and press, (3) the reaming operation, and (4) samples from the exterior corridor in the general vicinity of the fabrication line. In the grenade fabrication area, we obtained samples both from the breathing zones of the workers and from behind the partial lucite curtains that are used to control dust in some areas of the production line.

The sampling approach was to obtain Lovelace Multi-Jet Cascade Impactor (LMJ) (Newton et al. 1977; and Newton et al. 1981), LMJ/Parallel FLow Diffusion Battery (LMJ/PFDB) (Cheng et al. 1984), silver membrane filter and Nuclepore filter samples from selected sites in working areas of the Pine Bluff Arsenal during routine operations. The purpose of each sample type follows:

1. The LMJ/PFDB provides a size classified sample of aerosol from 0.05 μm mass equivalent diffusion diameter to about 10 μm aerodynamic diameter.
2. LMJ cascade impactor samples provide size distribution information and a measurement of total airborne mass in the size range of 0.5 to 10 μm aerodynamic diameter.

Table 1

Sampling Positions at the Pine Bluff Arsenal's M18 Grenade Production Facility

Mixing and Blending, Area 31-520

Operation Site		Sampling Site Work Station No.
Weighing of organic dye		Cubicle No. 15
Hallway		Near Cubicle No. 2

Main Production, Area 33-350

	Comment	
Partially fill cans and press	Dusty	1-8
Complete filling cans and press	Dusty	2-8
Reaming	Dusty	8-8
Corridor	No visible dust	N/A[a]

[a]N/A = not applicable. There was no work station in the corridor, which was an exterior area in the general vicinity of the fabrication line.

3. Silver membrane filter samples provide a measurement of total airborne mass concentration.

4. Nuclepore filters provide samples for electron microscopy.

RESULTS

Aerosol Sampling and Size Characterization

Table 2 lists the results of size distribution and aerosol concentration measurements as determined by the Lovelace Multi-Jet Cascade Impactors. Preliminary range-finding samples obtained in the most dusty areas of the production line indicated that there was no significant mass in the submicrometer mode. Therefore, the combined LMJ/PFDB aerosol sampler was not used in subsequent sampling. The highest airborne particle mass concentration measured was about 32 mg/m^3 inside the acrylic curtain at fill and press station #1. The actual particle concentration measured outside the acrylic curtain where the operator was stationed (and wearing a full face mask) ranged from about 0.6 to about 1.5 mg/m^3.

For the field sampling effort reported herein we used 10 μm aerodynamic diameter as the upper limit for respirability. The range of concentrations of respirable particles (< 10 μm, U. S. Federal Register, 1984) outside the acrylic curtains in the production area was 0.04 to 1.09 mg/m^3. Figures 2 and 3 are scanning electron photomicrograph (SEM) of particles collected on Nuclepore filters. These Nuclepore filters were subsequently cut into small enough pieces to be mounted on specimen stubs for the JEOL scanning electron microscope. A comparison of Fig. 2 ("pure" SY dye aerosols collected near weighing station) with Fig. 3 (aerosols collected near fill and press station) indicates that some of the aerosol particles collected near the production line had the physical shape of the pure SY aerosols.

Table 2

Results of Aerosol Sampling of the Pine Bluff Arsenal

M18 Grenade Fabrication Line

Sample Location	Sample Number	MMAD[a] (μm)	σ_g	Total Mass Conc. (mg/m^3)	Percent < 10 μm	Particles < 10 μm Conc. (mg/m^3)
Cubicle 15 Building #31-520 (Breathing Zone)	1	8.4 ± 2.4	5.6 ± 1.9	3.40	57	1.92
	2	> 15	4.1 ± 1.0	0.97	27	0.26
	3	13.7 ± 1.5	4.6 ± 0.6	1.07	46	0.49
	4	1.7 ± 0.6	4.6 ± 1.7	0.72	94	0.68
Hallway Near Cubicle 2 Building #31-520 (Breathing Zone)	1	3.7 ± 0.5	11.7 ± 3.1	0.94	70	0.66
	2	> 15	2.4 ± 0.1	0.35	13	0.04
	3	Not lognormal		0.20		0.20
Exterior Corridor Near Fill and Press (Breathing Zone)	1	2.7 ± 1.1	8.5 ± 5.8	0.44	76	0.34
	2	14.1 ± 1.2	1.7 ± 0.2	0.37	58	0.22
	3	Not lognormal		1.58	69	1.09
	4	10.0 ± 3.4	8.6 ± 2.9	0.78	44	0.34
	5	> 15	7.4 ± 3.6	1.45	52	0.75
	6	Not lognormal		0.55	50	0.28

Table 2

(Continued)

Sample Location	Sample Number	MMAD[a] (μm)	σ_g	Total Mass Conc. (mg/m^3)	Percent < 10 μm	Particles < 10 μm Conc. (mg/m^3)
Inside[b] Reamer Enclosure	1	13.5 ± 0.8	3.3 ± 0.3	4.65	41	1.91
	2	8.1 ± 0.2	2.8 ± 0.1	3.45	59	2.04
	3	13.0 ± 1.6	4.5 ± 0.6	7.17	46	3.30
	4	8.0 ± 0.2	2.5 ± 0.1	3.40	61	2.07
Reamer (Operator 1) (Breathing Zone)[c]	1	12.9 ± 2.6	3.2 ± 0.9	0.24	38	0.09
	2	5.1 ± 0.8	3.4 ± 0.6	0.58	70	0.41
	3	14.7 ± 8.5	6.3 ± 3.0	0.82	45	0.37
	4	Not lognormal		0.71	72	0.51
Reamer (Operator 2) (Breathing Zone)[c]	1	Not lognormal		0.71	60	0.43
	2	6.8 ± 0.5	3.3 ± 0.3	0.72	62	0.45
	3	6.0 ± 1.3	4.7 ± 1.2	1.14	64	0.73
	4	4.8 ± 1.6	6.7 ± 2.9	1.02	67	0.68
Inside Fill and Press Enclosure	1	10.0 ± 3.0	2.0 ± 0.1	5.15	53	2.71
	2	12.0 ± 0.7	3.6 ± 0.3	3.29	47	1.53
	3	> 15	3.0 ± 0.1	10.26	33	3.39
	4	8.9 ± 0.4	2.6 ± 0.2	4.97	57	2.84
	5	> 15	3.3 ± 0.5	12.46	23	2.87

Table 2

(Continued)

Sample Location	Sample Number	MMAD[a] (μm)	σ_g	Total Mass Conc. (mg/m^3)	Percent < 10 μm	Particles < 10 μm Conc. (mg/m^3)
Inside Fill and Press Enclosure	6	13.7 ± 0.7	2.8 ± 0.2	6.00	40	2.39
	7	11.3 ± 0.2	2.4 ± 0.1	32.0	45	14.5
	8	> 15	3.3 ± 0.2	10.80	27	2.89
	9	11.9 ± 0.4	2.4 ± 0.1	5.09	44	2.24
Outside Fill and Press Operator (Breathing Zone)[c]	1	Not lognormal		0.74	36	0.26
	2	0.1 ± 0.2	2.1 ± 5.7	0.68	89	0.60
	3	Not lognormal		0.66	50	0.33
	4	Not lognormal		1.48	43	0.63
	5	14.5 ± 1.4	1.9 ± 0.3	0.64	33	0.21

[a]Values for MMAD and σ_g are $\bar{X} \pm$ SE.
[b]Samples taken behind acrylic protective barrier (curtain).
[c]Samples taken from near breathing zone of worker outside the acrylic barrier.

Figure 2. Scanning electron photomicrograph of "pure" SY dye airborne particles collected on Nuclepore filters from the weighing area in Building 31–520.

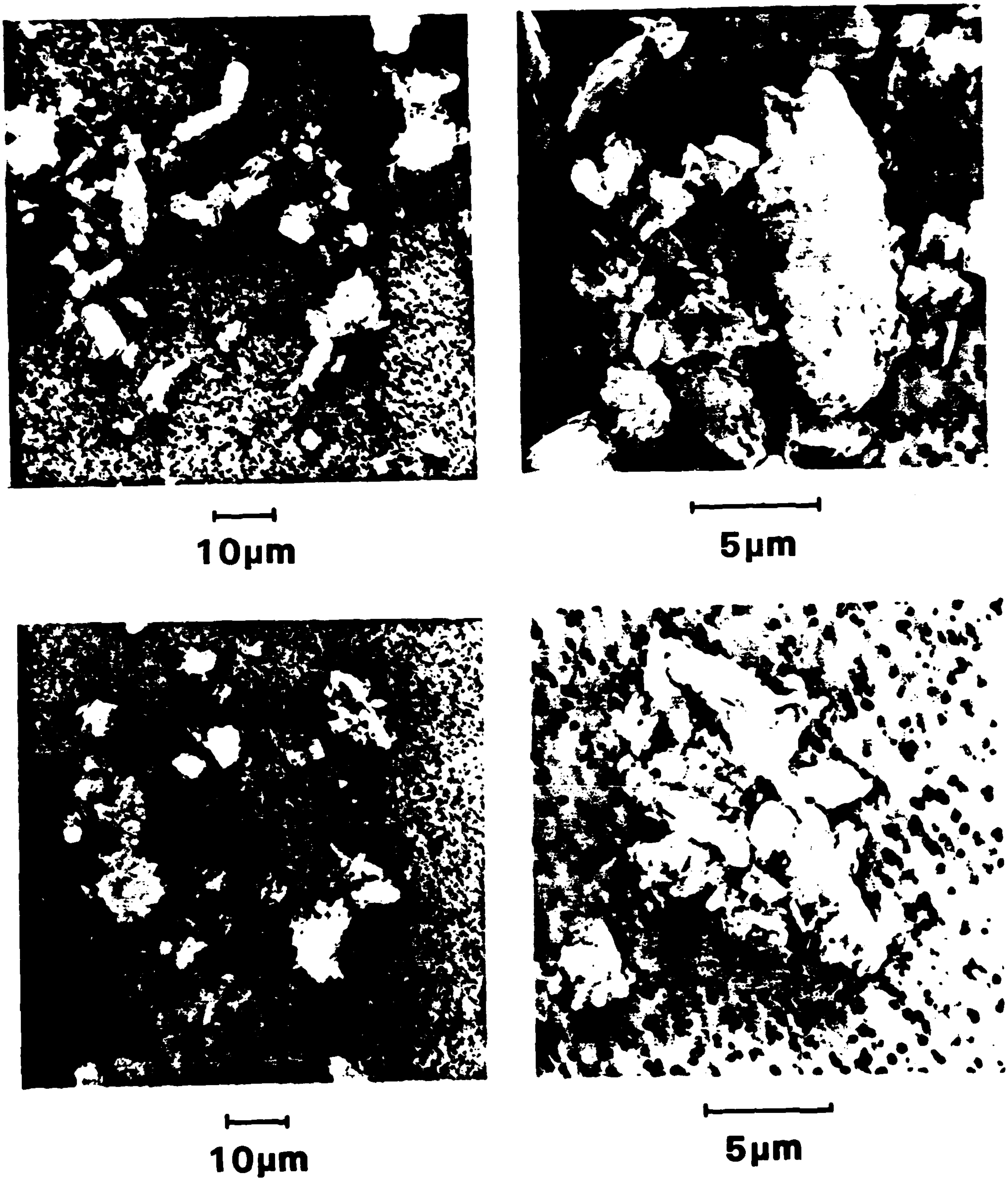

Figure 3. Scanning electron photomicrographs of airborne particles collected outside the acrylic barrier near the fill and press Station No. 1. Particles were collected on Nuclepore filters. The left column shows a low power magnification of the particles and the right column is a higher magnification of some of the same particles shown in the left column.

Chemical Analyses

Bulk munition material was analyzed for SY dye (QI) content by extracting triplicate 100 mg samples, three times each, with 15 mL of acetonitrile. The SY content in the bulk munition material was 36.9 ± 2.0 percent. A 2.4 g sample dried in a desiccator for 5 days at room temperature had a weight loss of 0.28 percent. This indicated that very little water was adsorbed by the bulk material. Filters from five sampling locations were analyzed for SY content to determine the amount of SY in the total particulate sample (Table 3). Samples collected near the production line had a dye content similar to that of the bulk mixture, while the sample collected near the weighing cubicle had a much higher SY content, as expected. No SY dye was detected in the filter samples from the exterior corridor by the reamer station. The masses and percentages of SY measured on cascade impactor stages from eight sampling locations are listed in Table 4. The purpose of the chemical analyses of the cascade impactor samples was to determine if the SY content of the aerosols was size dependent. In contrast to the filter samples, the cascade impactor samples taken in the corridors (at a different time than the filter samples) showed some SY content. The results suggest that a large fraction of the airborne SY dye was in particles larger than 10 μm aerodynamic diameter. Virtually no submicrometer SY aerosols were found. Because the percentage of dye in most of the aerosol samples was similar to that in the bulk mixture, the maximum mass concentration for dye in aerosols of a size that could be inhaled was < 0.5 mg/m^3 in areas occupied by the industrial workers.

Table 3

SY Content of Filter Samples

Sampling Location	Per Cent SY of Mass Collected
Inside Reamer	40.9
Reamer Operator No. 1	43.0
Fill and Press Area	45.4
Cubicle 15 (weighing of dye) Building 31-520	84.1
Corridor Near Fill and Press	0

Table 4
SY Content of Impactor Samples[a]

Sample Location	Impactor Stage No.*	µg SY	Percent SY in the Sample	SY Particles < 10 µm µg/m^3
Cubicle 15	1	1500	79	
Building #31-520	2	290	78	
(Breathing Zone)	3	260	72	
	4	290	79	
	5	130	67	
	6	14	16	
	7	2	3	
	8	2	1	285
Hallway Near Cubicle 12	1	36	13	
Building #31-520	2	4	5	
(Breathing Zone)	3	3	5	
	4	1	1	
	5	1	2	
	6	0.4	0.1	
	7	0.4	0.1	
	8	0.2	0.01	3
Exterior Corridor Near	1	260	20	
Fill and Press	2	94	23	
(Breathing Zone)	3	16	12	
	4	8	8	
	5	5	5	
	6	3	4	
	7	2.5	4	
	8	1	0.4	47
Inside Reamer Enclosure	1	2900	39	
	2	700	42	
	3	580	42	
	4	530	44	
	5	270	35	
	6	110	29	
	7	29	20	
	8	10	1.3	1211
Reamer (Operator 1)	1	50	14	
(Breathing Zone)	2	7	6	
	3	29	15	
	4	24	13	
	5	3	3	
	6	2.3	2.4	31
	7	0	N.A.	
	8	6	4	

Table 4 (Continued)

Sample Location	Impactor Stage No.[a]	μg SY	Percent SY in the Sample	SY Particles < 10 μm $\mu g/m^3$
Reamer (Operator 2) (Breathing Zone)	1	246	29.4	
	2	67.5	29.4	
	3	54	15.7	
	4	101	31.3	
	5	34.5	23.0	
	6	10.5	32.8	142
	7	4.5	N.A.	
	8	7.5	2.6	
Inside Fill and Press #1 Enclosure	1	2900	40	
	2	780	40	
	3	480	42	
	4	350	43	
	5	120	33	
	6	29	16	
	7	6	8	
	8	1	0.4	698
Outside Operator Fill and Press #1 (Breathing Zone)	1	650	38	
	2	76	30	
	3	71	33	
	4	58	28	
	5	25	23	
	6	7	9	63
	7	2	3	
	8	1	0.3	

N.A. = data not available because no total mass of original sample available.
[a]The effective cut off diameters in μm (ECD) for a nominal sampling rate are: stage 1 = 12.1, stage 2 = 7.7, stage 3 = 4.9, stage 4 = 3.0, stage 5 = 1.9, stage 6 = 1.2, and stage 7 = 0.7.

DISCUSSION

The filter samples from the M18 production area indicated that the SY content of aerosols ranged from about 41 percent to 45 percent. This is approximately the SY content of the bulk mixture. Filter samples from the weighing operation in Building #31-520 indicated an SY dye content of 84 percent. It is probable that the unaccounted mass was water vapor in this sample. This assumption was supported by data from a simultaneously obtained cascade impactor sample from the same area (Table 4). The first five stages of the cascade impactor had about 70 to 80 percent SY while the remaining two stages and final filter only had from 1 to 16 percent SY. This is consistent with the assumption that adsorption of the water vapor is proportional to surface area and that the surface area per unit mass is inversely proportional to the 2nd power of the diameter.

Table 2 lists the results of the cascade impactor sampling for size distribution, total airborne mass, and an estimate of the respirable sized fraction of the airborne mass. Because most of the dusty episodes that we observed were transitory, we have not reduced the data to mean values for either size distribution parameters or airborne mass concentrations. It is useful to calculate the effectiveness of the acrylic barrier curtains for the fill and press stations and the reamer station (Table 5). Inside the acrylic enclosures, the total airborne mass concentrations ranged from about 3.3 to a maximum of 32.0 mg/m^3. Subtracting the airborne mass larger than 10 μm aerodynamic diameter yields a range of 1.5 to 14.5 mg/m^3 as the respirable airborne mass. From Table 4, the SY content was about 40 percent of the

Table 5

Effectiveness of Acrylic Curtains
(Fill & Press and Reamer Stations)

INSIDE CURTAINS

Total Particles Concentration Range (mg/m^3)	Particles < 10 μm Concentration Range (mg/m^3)	Aerosolized SY Particles < 10 μm Concentration Range (mg/m^3)
3.3 - 32.0	1.5 - 14.5	0.6 - 5.8

OUTSIDE CURTAINS

Total Particles Concentration Range (mg/m^3)	Particles < 10 μm Concentration Range (mg/m^3)	Aerosolized SY Particles < 10 μm Concentration Range (mg/m^3)
0.24 - 1.48	0.09 - 0.73	0.04 - 0.29

Conclusion: The approximate reductions in concentrations due to the curtains was 10 to 20 fold.

total mass, indicating the SY dye airborne concentration range was 0.6 to 5.8 mg/m^3. Outside the acrylic curtains the maximum airborne SY (< 10 µm) mean concentration was about 0.3 mg/m^3 for both the reamer operator and the fill and press operator. From these data the acrylic curtains reduced the particle concentrations by 10 to 20 fold.

All cascade impactor samples analyzed for SY indicated that smaller particle sizes had very small amounts of SY as compared to the larger size cuts in the samples. This suggests that the samples had adsorbed water vapor or that the smaller size cuts were composed of material other than SY dye.

Although a filter sample from the corridor near the fill and press area indicated an unexpectedly high concentration of total mass, chemical analyses indicated that no SY dye was present in this aerosol sample. A cascade impactor sample obtained the next day from the same general area indicated an SY content range of 4 to about 20 percent. This suggests that anyone in the general vicinity of the fill and press areas could be exposed to transitory concentrations of SY dye of up to about 0.1 mg/m^3. In general, workers in this area did not wear respiratory protection.

From the SEM photomicrographs of the pure dye (Figure 2) we can see the basic morphology of the SY dye particle. Also shown in Figure 3 are the various particles that constitute the final smoke munitions mixture. In these composite photomicrographs, obtained from different locations along the M-18 grenade fabrication area, we can identify individual particles with a morphology similar to the "pure SY dye" particles.

The following statements summarize this field sampling study.

1. The maximum concentration of respirable (< 10 µm MMAD) SY aerosols detected outside protective curtains in the production area was < 0.5 mg/m^3.

2. Only about 50 to 70 percent of the mass of the aerosol containing SY dye was less than 10 μm aerodynamic diameter size.

3. The calculated geometric standard deviations (σ_g) were all quite large and tended to support the hypothesis that the aerosol was not lognormally distributed.

4. No submicrometer aerosols of SY dye were found.

5. There was a factor of about 10-20 difference in the aerosol concentration inside the lucite enclosures as compared to the workplace stations (outside). This indicates the efficiency of the lucite curtains in reducing the exposure for workers.

6. The airborne SY dye found in the corridor near the fill and press stations was transitory and probably was strongly influenced by dumping operations in which a worker dumps large batches of the mixture into smaller containers for use in the fill and press operations.

7. These aerosol data for fabrication of the yellow (SY) M18 smoke grenade can be extrapolated to provide basic data for other similar M18 colored smoke grenade manufacturing processes. Caution is advised for assuming other dyes would have similar size distribution parameters. Until aerosol measurements are obtained for other colors of dyes during grenade fabrication, these data could only be used for "order of magnitude estimates."

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